OPTIMIZATION OF MACHINING PARAMETERS OF TITANIUM ALLOY IN ELECTRIC DISCHARGE MACHINING BASED ON ARTIFICIAL NEURAL NETWORK

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion, this report is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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STUDENT DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This report presents the artificial neural network model to predict the optimal machining parameters for Ti-6Al-4V through electrical discharge machining (EDM) using copper as an electrode and positive polarity of the electrode. The objective of this paper is to investigate how the peak current, servor voltage, pulse on- and off-time in EDM effect on material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR). Radial basis function neural network (RBFN) is used to develop the Artificial Neural Network (ANN) modeling of MRR, TWR and SR. Design of experiments (DOE) method and response surface methodology (RSM) techniques are implemented. The validity test of the fit and adequacy of the proposed models has been carried out by doing confirmation test. The optimum machining conditions are estimated and verified with proposed ANN model. It is observed that the developed model is within the limits of the agreeable error with experimental results. Sensitivity analysis is carried out to investigate the relative influence of factors on the performance measures. It is observed that peak current effectively influences the performance measures. The reported results indicate that the proposed ANN models can satisfactorily evaluate the MRR, TWR as well as SR in EDM. Therefore, the proposed model can be considered as valuable tools for the process planning for EDM and leads to economical industrial machining by optimizing the input parameters.

ABSTRAK

Laporan ini membentangkan kajian tentang *artificial intelligence model* untuk meramal parameter yang terbaik bagi pemesinan Ti-6AL-4V dengan menggunakan mesin nyahcas elektrik (EDM) dan tembaga dengan polarity posifit sebagai elektrod. Tujuan kajian ini adalah until megkaji bagaimana arus puncak, kuasa voltan, masa pemberhentian pulsa dan masa pembukaan pulsa dalam EDM mempengaruhi kadar pemesinan bahan (MRR), kadar kehausan alat (TWR) dan kekasaran permukaan (SR). *Radial basis function neural network* (RBFN) digunakan untuk membina *Artificial Neural Network* (ANN) untuk permodelan MRR, TWR dan SR. Kaedah desain eksperimen (DOE) dan metodologi respon permukaan (RSM) telah dilaksanakan. Kesahihan dan ketepatan model yang dicadangkan dibuktikan dengan menjalankan ujian pengesahan. Keadaan memesin yang terbaik ditafsir dan disahkan dengan model ANN yang telah dicadangkan. Daripada model yang dibina, dapat diperhatikan bahawa ralat antara model yang dibina dengan keputusan eksperimen masih dalam kadar yang boleh diterima. Analisis sensitivity dilakukan untuk mengkaji pengaruh relatif oleh factor-faktor mesin terhadap prestasi yang diukur. Keputusan yang dilaporkan menunjukkan bahawa model ANN boleh menilai MRR, TWR dan SR. Oleh yang demikian, model yang dicadankan boleh dianggap sebagai satu alat untuk merancang pemesinan EDM dan dapat member hermat dalam industry pemesinan dengan memasukkan parameter pemesinan yang optima.

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LIST OF SYMBOLS

W_{w1}	Weight of workpiece before machining
W_{w2}	Weight of workpiece after machining
T	Time taken for the machining
W_{e1}	Weight of electrode before machining
W_{e2}	Weight of electrode after machining
Y	Performing parameter
X	Response to neural network
W	Weight matrix
f	Model of process that is being used in the training
v	Induced local fields produced
x	Input signal
w	Synaptic weight
H_l	Hidden layer one
Z_j	Hidden layer two
O_k	Hidden layer three
Y_o	Output at the output layer
w_{li}	Synaptic weight from the input neuron
i (x_i)	Input neuron
w_{jl}	Synaptic weight form neuron l in the first hidden layer to the neuron j in the second hidden layer
w_k	Synaptic weight from neuron j in the second hidden layer to the neuron k in the last hidden layer to the output neuron o.

LIST OF ABBREVIATIONS

EDM	Electric-Discharge machine
EWW	Loss electrode
MRR	Material removal rate
SR	Surface Roughness
TWR	Tool wear rate
WRW	Weight loss of workpiece

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Titanium alloy is increasing use in many industrial and commercial applications because of its excellent properties. The largest consumer of titanium alloys is the aerospace industry and is increasingly more used in chemical machine building, shipbuilding and auto industry, in equipment fir the oil and gas industry, food industry , medicine and civil engineering. Application of Ti-6Al-4V are use in engineering application because of its outstanding corrosion resistance, fatigue resistance, and sufficient corrosion resistant in many environment especially in high strength applications.

Ti-6Al-4V is α+β alloys which contain a larger amount of β stabilizers (4-6%). Beta alloys can be heat treated to develop variety of microstructures and mechanical property combinations. Alloy VT6 has the following chemical composition (wt. %): Al, 5.5–7.0; V, 4.2–6.0. The content of impurities should not exceed (wt. %): C, 0.10; Fe, 0.30; Si, 0.15; O2, 0.20; N2, 0.05; H2, 0.015 (Moiseyev, 2006). Titanium alloy is hard to be machine due to the properties of it. Hence Electrical discharge machining (EDM) is used. EDM is a non conventional, thermo electric process in which the material from work pieces is eroded by series of discharge sparks between the work and tool electrode immersed in a liquid dielectric medium (Yang et al., 2009). EDM technology are develop and are widely use in applications such as die and mild machining, micro-machining, and prototyping. Among all EDM processes, die sinker EDM is widely use (Fonda et al., 2008). Die sinking EDM is a machining process where positive feature shapes on the workpieceare mapped from the negative features in the electrode. It is

relatively low machining process and it require electrode made specially for machining of a given product. The advantage of EDM machine is its ability to produce small, even micro features. The EDM process is used mostly for making dies and moulds (Valentilic et al., 2009). In order to get a good quality parts with minimum cost there are several parameter in the EDM that have to be control. There are the polarity, pulse on duration, discharge voltage and discharge current are several parameter that need to be control.

Advance in information and communication technology have force industrial activities to use computers in each phase of manufacturing process. This has put computerization at the forefront of competitive factors in manufacturing business. Hence Artificial Intelligence (AI) is introduce into the industry. AI is a branch of computer science dealing with the design of computer systems that exhibit characteristic associated with intelligence in human behavior including reasoning, learning, self-improvement, goal-seeking, self maintenance, problem solving and adaptability (Shin and Xu, 2009). In other words it is the discipline concerned with the development and application of computational tools that mimic or are inspired by natural intelligence to execute tasks with performances similar to or higher than those of natural systems. There are a lot of different tool in AI. Neural Network (NN) is one of the technique use in AI. NN is a computational model of the human brain that assumes that computation is distributed over several simple interconnected processing elements called neurons or nodes, which operate in parallel. NNs can capture domain knowledge from examples. Do not archive knowledge in an explicit form such as riles or data bases, can readily handle both continuous and discrete data, and have good generalization capability. NNs can be employed as mapping devices, pattern classifiers or patters completers. Application in manufacturing engineering range from modeling, prediction, control, classification and pattern recognition, to data association, clustering, signal processing and optimization

1.2 PROBLEM STATEMENT

Titanium alloy in industry has high strength-weight ratio, high temperature strength and exceptional corrosion resistance. Titanium alloy are difficult to be machine due to its chemically reactive with almost all cutting tool materials and its low thermal

conductivity and low modules of elasticity impairs machinability. In EDM, electrode and workpiece does not make direct contact. Therefore titanium can be machined effectively using EDM (Hascalik and Caydas, 2007). EDM machining, the selection of proper parameter is important. Improper combination of parameter may cause low material removal rate (MRR) and also high tool wear ratio (TWR) which impose high cost on manufacturer. Effective machining needs high surface quality with minimum electrode erosion. Optimization of EDM parameter by finding the correct combination of the parameter available in EDM will enhance the machining productivity and reliability.

1.3 OBJECTIVES

The objectives of this project are as follows:

i) To investigate the machining characteristic on titanium alloy (Ti-6Al-4V).

ii) To optimize the EDM machining parameter of Ti-AL-4V in term of MRR, TWR base on artificial neural network model.

1.4 PROJECT SCOPES

This research is limited to machining by using EDM die sinking, the material used which is Ti-Al-4V and also EDM parameter that will be consider in the research are the dielectric fluid, polarity, pulse-on-duration, discharge current and discharge voltage. Because of cost and availability limitation the electrode that is use is copper. Copper with its properties of high density, low electrical resistively and high hardness make it suitable for this research. MRR can be calculated by measuring the amount of material being removed after a certain period of machining and the electrode wear ratio is calculated after measuring the weight of the electrode and workpiece before and after machining. Radial Basis Function (RBF), Neural Networks is use for modeling of this research.

1.5 OVERVIEW OF REPORT

This report consists of five chapters. Chapter 1 presents background, problem statement, objectives and the scope of the project. Chapter 2 discusses the literature review related to EDM, titanium, alloy and AI. The methodology of this study which includes method, strategy and approaches are explain in Chapter 3. Results, analysis and discussion of this study are stated in Chapter 4. Chapter 5 presents the conclusion and recommendation of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter provide a review of past research related to EDM machining and its parameter, titanium alloys and also AI. The review offers different approach in this present project so that it can be properly modified to add to the present of literature as well as to justify the scope and direction of present research effort.

2.2 ELECTRICAL DISCHARGE MACHINING

2.2.1 History of EDM

EDM machining techniques was discovered by and English Scientist in the 1770s but it is not fully taken advantage until 1943 when Russian scientist learned how the erosive of the technique could be controlled and used for machining purposed. EDM machining was very imprecise and riddled with failures during the 1770s and is commercially developed in mid 1970s. Wire EDM began to viable technique that held shape the metalworking industry we see today. In mid 1980s, the EDM techniques was transfer to a machine tool. This migration made EDM more widely available and appealing over traditional machining process.

2.2.2 EDM Machining

EDM is a machine use to cut hard material or material which is difficult to machine with traditional techniques. It is often being categories as non-traditional or

non-conventional group of machining method. This method can be use to machine all type of metal including alloys which are hard to be machine by conventional machine. It is also can be use to cut complex shape and geometry with small shaped angles and detailed contours or cavities within parts and assembly. EDM are commonly used in tool and die industry to produce mould and die component. Currently EDM has become a integral part for making prototype and production parts but it only work with material that are electrically conductive (Jameson, 2001). There are two types of EDM machine which is Die-sinking EDM or also known as ram EDM, and Wire EDM. Die-sinking EDM machine need the electrode to be in the exact opposite shape of the workpiece, while wire EDM uses continuous wire as electrode. Machining occur by controlling the sparks between the electrode and the workpiece in the presence of dielectric fluid where the electrode can be considered to act as cutting tool.

Dielectric fluid is usually a petroleum product or deionized water usually die sinker machines use hydrocarbon dielectric fluids. Dielectric fluid functions for spark machining is that it prove a known electrical barrier between the electrode and workpiece, cooling for the electrode and workpiece, cooling for the vaporized material that becomes the EDM chip upon solidification and for removal of the EDM spark debris form the sparking gap. Dielectric fluid is an insulator that resist the flow of electricity until voltage is high enough to cause the fluid to change into an electrical conductor applied which is called the ionization point. As the spark electricity flow between the electrode and the workpiece, heat is generated, and dispersed within the electrode and surround the sparking area. The dielectric fluids help to remove heat as it surround the sparking area. It also cools and remove chip. As vapor cloud is form in the sparking-gap area which is then cool and solidifies produce a sphere with a hollow center known as the EDM chip. This chip is then remove by having dielectric fluid flowing through the sparking gap and then transport the chips out of the sparking area.

2.2.3 EDM Parameters

There are a lot of studies had been done in finding a good combination of parameter in EDM machining regardless the type of material to be machine nor the electrode that is used in the machining. Apart from that, modeling by using various types of artificial intelligent tools had also been performed. A study of EDM machining of titanium alloy (Ti-6Al-4V) had been performed by Hascalik and Caydas (2007). From their research, it had been found that the value of MRR, EWR and surface roughness has the tendency to increase with increasing current density and pulse duration. Even though in increases with pulse duration, at a long pulse duration such as 200 μs, it will decrease MRR and the surface roughness of the workpiece machine.

Krishna et al. (2009) has development of hybrid model and optimization of surface roughness in electric discharge machining using artificial neural networks and genetic algorithm. They found that in EDM machining, the current increases at constant voltage surface finish reduces tremendously. For machining of titanium, the machining current less than or equal to 15 is more suitable. From this research, they had come out with a conclusion that it has good surface finish at voltage 40V and at constant current of 16A. ANN models are develop for surface roughness which can predict the behavior of these material when machined on EDM. The developed models are within the limits of agreeable error for all performance measures considered. Investigation into the electric discharge machining of hard tool steel using different electrode material done by Singh et al. (2004) uses copper, copper tungsten , brass and also aluminum as electrode. From their research, work piece machine by copper and aluminum electrodes offer higher MRR. Copper and copper tungsten over comparatively low electrode wear or the tested work material. At high values of currents, copper and aluminum offer low surface roughness. Hence copper is a better electrode material.

Erden (1983) has made a research on the effect of materials on the mechanism of electric discharge machining. From this research, spark gap is consider when selecting an electrode size to achieve a particular hole diameter. Frontal spark

gap determines the ultimate depth of the blind hole. The variation between discharge in term of their electrical characteristic and strike location within the gap is influenced by several factors. It is established that only spark pulses are responsible for metal erosion. Short circuit, open circuit arcing pulses are collectively termed as ineffective pulse. It has been experimentally investigated that during EDM there is an appreciable amount of diffusion of metals from the tool electrode to the work material and vice versa. In order to the maximize quality and minimum cost in EDM machining, optimization on the parameter that will effect this factor is important. There are few important parameter that need to be considered in EDM machining. There are:

i) Source voltage can be determine by the width of gap between the electrode and workpiece, higher voltage creates current and spark across wider gap.
ii) Discharge current is the value of the current applied to the electrode during pulse on-time in EDM. It is one of the primary input parameter of an EDM process and together with discharge duration and relatively constant voltage for given tool and workpiece materials.
iii) Arc gap is the distance between the electrode and workpiece during the process of machining also know as sparking gap.
iv) Pulse on-time is the time of which current is applied to the electrode during each EDM cycle. The materials removed is directly proportional to the quantity of energy applied during pulse on-time. This energy is controlled by the current and the on-time.
v) Pulse off-time is the waiting interval during two pulse on-time periods. Melted and solidified particles are removed form the setting during this period.

Apart from electrical parameter, non electrical parameter also influence the performance of EDM machining which are the electrode used and also dielectric fluid. The electrode that are commonly use is EDM machining are tungsten, copper tungsten, silver tungsten, yellow brass, chrome plated material, zinc alloys, tungsten carbide, copper and graphite. Copper electrode are commonly used in resistance

capacitance circuits where higher voltages are employed while graphite electrodes are commonly used in application requiring low tool wear and high material removal. Brass material are mainly used in pulse type circuits because of their good machinability (Salman et al,. 2008)The properties of some electrode are shown in the Table 2.1.

Table 2.1: Properties of electrode (Hascalik and Caydas, 2007)

Material	Gaphite	Copper	Aluminium
Density (g/cm^3)	1.77	8.905	27.5
Melting point (°C)	3300	1083	660
Electrical resistively (μΩ cm)	1400	8.9	14.2
Hardness (HB)	7	100	40

Two commonly used dielectric fluid are kerosene and distilled water. Dielectric fluid act as an insulator until enough voltage is supply to cause it to change to electrical conductor (Jameson, 2005). Water is a good insulator but it has several disadvantages to be use as dielectric fluid where it causes rust towards the electrode, workpiece and also the machine itself, and also during electric discharge it separates water into pure hydrogen and pure oxygen which is a very explosive pair. Kerosene is a better choice of dielectric fluid where it does not have rust problem and no dangerous gases are produced. The choosing of dielectric fluid is based on the type of material ad the process that are made or used.

2.3 TITANIUM ALLOY

Titanium alloy is to be consider as a rather new material used in the market for manufacturing purpose. It has been become one of the essential metal materials for modern machine building. The use of titanium alloy . various engineering field is due to its high specific strength and high temperature strength within a broad temperature range, and also high corrosion resistance. Comparing to other metal, titanium have lower values of thermal conductivity, electrical resistance and thermal expansion.

Titanium alloy are divided into three groups which is alloys based on solid α- and β- solution, alloy based on solid solutions with some chemical compound and alloy based on chemical compound. Titanium exists in two allotropic modifications which is high temperature and low temperature. α- titanium exists at temperature below 882°C and β-titanium at higher temperature up to the melting point (Moiseyev, 2006).The largest consumer of titanium alloys is the aerospace industry. Recent decade, titanium and it alloys have been increasingly more used in chemical, machine building, shipbuilding, medicine, auto industry, food industry and also in equipment for the old and gas industry. In aircraft, the use of titanium alloy reduces the weight of aircraft construction and gives a higher weight efficiency. Figure 2.1 and Figure 2.2 shows some of the application of Ti-6Al-4V in automotive and biomedical industries.

Figure 2.1: Parts make by Ti-6AL-4V

Figure 2.2: Femur bone implant

In this research high strength titanium alloy is use which is Ti-6Al-4V also known as VT6. Ti-6Al-4Vare used worldwide as commercial material. Table 2.2 and Table 2.3 below shows the chemical and mechanical properties of Ti-6Al-4V.

Table 2.2: Chemical composition of Ti-6Al-4V alloy (wt.%) (Hascalik and Caydas, 2007)

Chemical composition	%
Ti	89.464
Al	6.08
V	4.02
Fe	0.22
O	0.18
C	0.02
N	0.01
H	0.0053

Table 2.3: Mechanical properties of Ti-6Al-4V (Hascalik and Caydas, 2007)

Work material	**Ti-6Al-4V**
Hardness (HV20)	600
Melting point (°C)	1660
Ultimate tensile strength (MPa)	832
Yield strength (MPa)	745
Impact-toughness (J)	34
Elastic modulus (GPa)	113

2.4 ARTIFICIAL INTELLIGENCE

Manufacturing of complex system can be conceptually thought as being an integrated whole of complex interacting subsystem. A manufacturing system takes in customer needs, feedback and part of society total energy and transform them to produce outputs or product with more efficiency. In concerned with the development and application to perform this task, Artificial Intelligence (AI) tool had been develop.

AI is a branch of computer science dealing with the design of computer system that exhibit characteristic associated with intelligent in human behavior. It is concern with the development and the application of computational tools that are inspired by natural intelligence to perform task with similar or higher performance that those of natural system. AI have brought new opportunities and challenges for researches to deal with complex, uncertain problems and systems, which is difficult or could not be solved by traditional method. Many traditional approaches that have been developed for mathematically well defined problems with accurate models may lack in autonomy and decision making ability and hence cannot provide adequate solutions under uncertain fuzzy environments (Shin and Xu, 2009).

Numerous AI tools, techniques and paradigms have been applied such as Fuzzy Logic (FL), Neuro-Fuzzy, Simulate Annealing (SA), Neural Network and